



Electricity auctions in South America: Towards convergence of system adequacy and RES-E support



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ARTICLE INFO

Article history:

Received 17 September 2013

Received in revised form

26 June 2014

Accepted 7 July 2014

Keywords:

Electricity auctions

Capacity mechanisms

System adequacy

Renewable energy

ABSTRACT

Regulatory reforms of the electricity industry in South America have always been prompted by the need of attracting enough investment to cover the fast-paced demand growth. In order to achieve this goal, the countries in the region which in the eighties and early nineties opted for market-oriented schemes, have rebuilt in the last decade their regulatory frameworks around long-term auctioning. These new mechanisms, initially implemented to attract investment in any sort of conventional generation technology so as to ensure the system adequacy, are also being increasingly used to bring in non-conventional renewable energy resources. These schemes have been until now run in parallel, but the steep learning curve of Renewable Energy Sources for electricity (RES-E) technologies is apparently opening the door to the implementation of new tendering procedures open to all kinds of generation technologies. In this article, we review the auction mechanisms for new generation implemented in South America. We argue that although the first impression might lead to the conclusion that conventional and RES-E technologies are in some cases close and even ostensibly competing in the same auctions, the fact is that the full convergence is still far to happen, as the rules and products applied to the different technologies differ significantly.

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1. Introduction

South America is a region which has shown high economic growth rates during the last decade. Energy consumption, and particularly electricity demand, has followed this economic development. Summing up the annual electricity demand of Argentina, Brazil, Chile, Colombia and Peru (statistic elaboration based on EIA [1]), it is possible to observe an almost constant increase from 307.6 TWh in 1990 to 483.2 TWh in 2000 (with an average annual rise of 4.63%), to 695.7 TWh in 2010 (with an average growth equal to 3.75% per year). Looking at these figures, it appears evident that the main challenge for the power sectors in the region is to guarantee a capacity expansion capable of covering this fast-paced demand growth.

1.1. The diversity in generation mix and potential

The electric power systems in the region are very diverse, in terms of prevailing generation technologies, availability of fossil fuels, and hydropower potential. For instance hydropower dominates the

generation mix of the Brazilian system but accounts for less than 40% of Chile's power system. Fig. 1 presents a comparison of the technology shares in the generation mixes of the five countries analysed in this paper.

An even more interesting factor is the potential evolution of the generation mix, i.e. the technologies and resources available for the expansion of these power sectors, since the systems in the region have a very large spectrum of possible options. The hydropower potential is far from being exhausted; the average rate of exploited/physically-potential hydropower is below 15% (statistic elaboration based on OLADE, [2]). Very large reserves of natural gas have been recently discovered, opening the field to the installation of combined cycle gas turbines. Also coal is widely available and it is not subject for the moment to environmental restrictions related to CO₂ emissions. The nuclear energy option, although rather rare until now (only present in Brazil and Argentina), has not been ruled out, so in principle it cannot be fully discarded, and non-conventional renewable energy technologies (not only wind and solar, but also biomass and even geothermal) have a huge potential. Furthermore, South America is endowed with one of the largest non-conventional renewable energy potentials in the World: strong and persistent wind flows, suitable conditions for small-hydro exploitation, significant solar power resources, and availability of biomass, especially from agricultural waste. Fig. 2 shows a graphical representation of this huge “green” potential in the region, as regards solar and wind energy.

This broad range of alternatives is obviously an advantage for these countries, but, paradoxically, it “complicates” the planning and expansion of power systems and, as a consequence, the design of long-term electricity auctions, because of the several different directions that the systems may take.

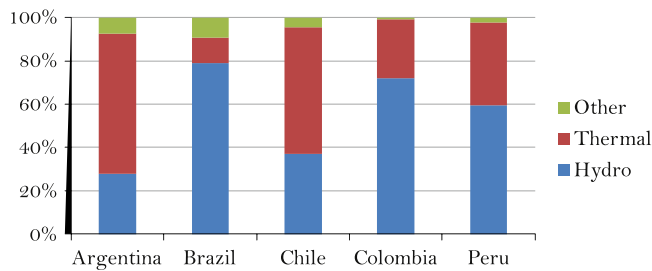


Fig. 1. Comparison of the electricity generation mixes. Data for 2010 [1].

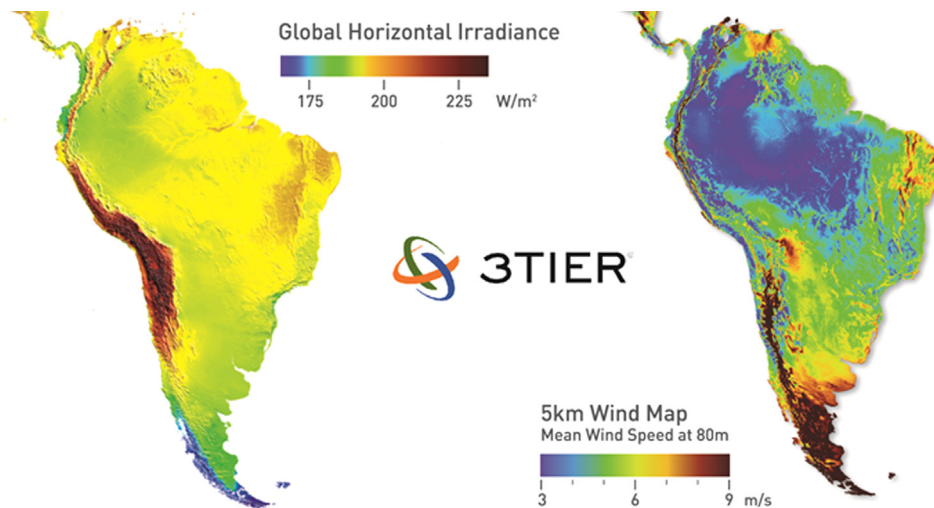


Fig. 2. Solar and wind energy potential in Latin America. Maps from 3TIER.

In the last decades South American countries have focused their efforts towards the achievement of another important “social” target, i.e. the increase of the electricity access to the largest share possible of their population. This, combined with the lack of pressure to fulfil any international commitment on emissions reduction (no country in the region is included in the Annex I of the United Nations Framework Convention on Climate Change), sidelined the promotion of the still-emerging RES-E technologies. Nonetheless, this situation is changing swiftly and several initiatives resulted in the implementation of renewable energy projects throughout the region.

The reasons behind this new push in favour of RES-E, besides the observed steep learning curve of some of them, are diverse (see Barroso and Batlle, [3]):

- RES-E represent the opportunity to diversify the current generation mix, in many cases heavily based on hydropower. Furthermore, some of them, as wind and biomass, present seasonalities which are complementary to hydro periodicity, (see e.g., Chade Ricosti and Sauer [4]) for a good discussion on the interaction between wind and hydro in the Brazilian context.
- The comparatively short construction times of RES-E turn them into a valuable alternative to avoid under or over procurement, especially taking into account the demand growth rates in the region and the long lead times demanded by hydro plants.
- RES-E are often the most efficient solution to improve the access to electricity for a large number of people living in the numerous isolated areas in the region.

On top of this, the high proportion of large-reservoir hydro plants in these systems provides an abundant storage and fast ramping capability that mitigates the extreme impact of the intermittency and non-dispatchability of RES-E technologies.

However, while “conventional” large hydro plants already play a major role in the power sectors of the region, these non-conventional RES-E are almost still untapped and at the moment they represent quite a negligible share of the generation mix.

1.2. The regulatory pursue of new investments in generation

South America has been the cradle of the power sector market reforms. In 1982 Chile issued its Electricity Act, which considered the unbundling of vertical-integrated utilities and the introduction of market competition in those sectors not identified as natural monopolies, a scheme which would then be implemented all over the world in the following decades. This pioneering reform became a model for several South American countries such as Argentina (1992), Peru (1992), Colombia (1993) and Brazil (1994) which restructured their power sectors following to a larger or lesser extent the guidelines of the Chilean liberalisation. The conceptual background of these reforms lied in the marginal pricing theory, according to which, under simplifying hypotheses, the market marginal price is the only economic signal required to drive investments towards the optimal generation mix. However, several regulators, considering the unfulfilment of the abovementioned simplifying hypotheses,¹ complemented from the very beginning of the short-term market prices with some sort of capacity mechanism (capacity payments, capacity markets, or both), in order to provide investors with a further incentive, the main exception to this scheme being Brazil, which relied in a quantity scheme and required consumers to have a percentage of

their load covered by contracts with physical backing (such percentage was 85% when the reform started and is now 100%).

Despite all these measures, in the last decade of the twentieth century the original designs started showing their limitations, mainly in one particular area: the long-term security of supply. Short-term market prices, especially in those countries with large hydropower shares of the generation mix, were considered too volatile to be an effective driver for new investments and the strong governmental influence on the sector was perceived as a threat by foreign capitals. For a number of reasons (ill design and regulatory interference), the capacity mechanisms did not work as expected and the expansion of the electricity supply was not able to follow the fast-paced growth in demand. This resulted in the narrowing of reserve margins, high prices and in some cases serious shortage situations (see Batlle et al., [5]). In face of this issue, regulators in the region looked for new reforms to tackle the matter, in which they abandoned the original idea according to which capacity expansion was supposed to be led just by private investors' initiatives. As next described, the backbone of these reforms was the implementation of all sorts of long-term auctions.

1.2.1. Long-term auctions to guarantee system adequacy

A new mechanism, able to guarantee an economic-efficient expansion of the electricity supply, was to be designed in order to deal with the lack of investment. In 1999, an innovative proposal, based on the so-called “reliability options” mechanism, subsequently described in full in Vázquez et al. [7], was proposed in the Colombian context. Although this design was finally not implemented until 2006, the discussion was already taking place all over the region. In 2004 Brazil finally launched a new scheme, based on electricity auctions. Similar long-term auction mechanisms, with minor or more important variations, were implemented in other countries, such as Chile in 2005 and Peru in 2006. As stated, in 2006 Colombia introduced a scheme based on the reliability-option proposal. The conceptual background of this second wave of reforms lied in the long-term contracting: fixing in advance and through a competitive mechanism part of the generators remuneration hedges the risks related to the volatility of the short-term market price and to potential regulatory interventions. Fig. 3 represents graphically these two regulatory waves: the first one, from vertical-integrated monopoly to liberalisation and market competition, originated by the pioneering Chilean reform; the second one, from capacity mechanisms to long-term electricity auctions, inspired by the Colombian and the Brazilian experiences.²

Long-term electricity auctions are now the driving force for the expansion of the power sectors in South America and they have already been described in literature (e.g., Moreno et al., [8]). Also in the context of RES-E support mechanisms, after some initial and isolated subsidisation programmes, the current trend is to carry out renewable energy auctions.

1.2.2. The increasing push for RES-E: from traditional support mechanisms to auctions

At the beginning of the century, a few number of South American countries introduced national RES-E support programmes. Examples of these programmes were the Argentinean “National System for the promotion of electricity from RES” (Law 26.190 of 2006) and the Brazilian “PROINFA Programme” (Law no. 10.438 of 2002). These first schemes relied on the so-called price-based mechanisms.³ Although they were responsible for bringing

² As shown in the chart, Argentina is following a different approach, later described in this paper.

³ For a detailed classification of RES-E support mechanisms, see Batlle et al. [9]

¹ For a detailed discussion on these hypotheses, see Rodilla and Batlle, [6].

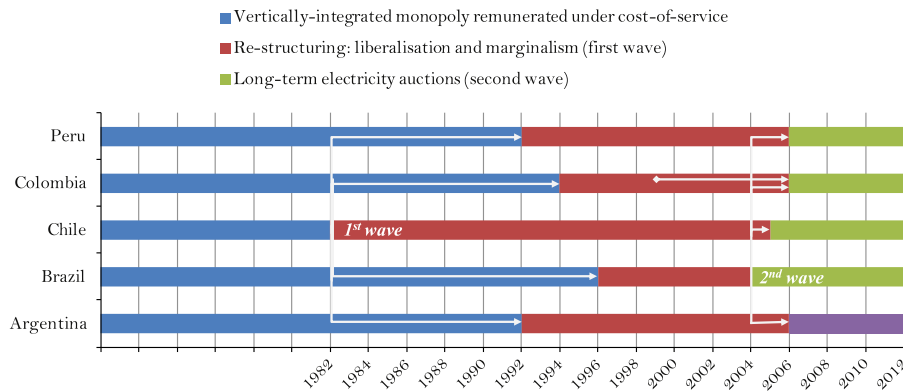


Fig. 3. First and second wave of regulatory reforms in South America.

the first MW of RES generation to these countries, their results were criticised on the grounds of their low economic efficiency (administrative definition of a feed-in tariff) and implementation process (most projects delayed years to start operation with respect to the planned commercial operation date).

Therefore, while long-term electricity auctions were acquiring a central role in the regulation on the security-of-supply level, also the RES-E support frameworks started to move towards renewable energy auctions (quantity-based mechanisms). In the auction-based approach, the winning bidders are usually offered a long-term contract for the production of renewable electricity, thus reducing the uncertainty for RES-E generators. RES-E-specific auctions have been implemented in four countries in the region (Argentina, Brazil, Peru and Uruguay) and in some cases they have resulted in very low electricity prices if contrasted with similar experiences in comparatively more mature markets, especially if it is taken into account that the common interest rates required by investors in the region are significantly higher. On the other hand, it can be stated that priced-based mechanisms are disappearing from the regulation in the region.⁴

1.2.3. Towards a common level playing field

The aim of this article is to develop a comprehensive review of the long-term electricity auction designs implemented in the region for both system-adequacy and RES-E-support. The review is built around a previous discussion on the key auction design elements. As analysed, in some cases there are significant signs that a certain convergence in both purchasing processes is taking place. For instance, in Brazil and in Colombia wind turbines can compete with conventional generation technologies in non-technology-specific auctions. We discuss which are the remaining differences that should be harmonised to achieve this convergence.

2. Electricity auctions design elements

As mentioned above, long-term electricity auctions, aiming either at guaranteeing the adequacy of the system or at RES-E support, share a common objective: to foster the entrance of new capacity by fixing in advance part of the investors' remuneration, thus hedging their risk. However, several different auction designs can be implemented to achieve this goal, as mentioned in Maurer and Barroso [10]. It is not possible to identify a "one-size-fits-all" mechanism, because auctions must be tailored to the electricity

system and regulation of the country where they are applied. The comparison of these schemes will be carried out on the basis of the main design elements which characterise electricity auctions. These design elements are introduced in this section and then reviewed in the following chapter for each auction mechanism.

- **Buying side:** The main options are to involve only the captive demand (regulated consumers) or the whole system demand (free and regulated customers), but more complex alternatives are possible. The key question behind the selection of this design element is: who has to pay for system adequacy? Who has to pay the costs related to RES-E support? Which consumption is the regulator going to secure?
- **Level of centralisation:** It must be decided who is responsible for the demand forecasting and which entity is in charge of carrying out the auction process. As regards demand prediction, this task can be either left to distribution companies or centrally assumed by the regulator, through the transmission system operator or an associated planning agency. On the other hand, the auction process can be centralised (all the demand is joined together and procured in the same auction) or decentralised (each entity, e.g., a distribution company, launches a separated auction, under the supervision of the regulator).
- **Selling side:** It has to be determined who (e.g., existing plants and/or new generation facilities) and under which conditions can take part in the auction (e.g., existing plants in some cases can only be price takers in the auction, or the capacity or energy to be offered by hydro plants can be administratively limited).
- **Contract terms:** Even in decentralised designs, the contract conditions usually have to follow strict indications by the regulator. In these provisions, for example it must be specified that the underlying physical coverage capability to be provided by the seller (the so-called firm capacity, or firm energy, e.g., tested production in the defined as peak hours in the so-called dry season), the so-called lead time (or lag period, i.e. the time that separates the signature from the date when the contract enters into force), the contract duration (e.g., seven or twenty years), etc.
- In other words, there are innumerable design elements which have a significant impact on the auction results. In this paper we will try to highlight the ones that make the difference between conventional and non-conventional generation (RES-E), in order to allow discussing which is the way ahead towards the future convergence of the different auction mechanisms.

In particular, we will argue that, besides lag period and contract duration, which are related to the different project finance structure of the different technologies (e.g., more or less capital

⁴ Chile, as later described, implemented a renewable obligations market, i.e. a quantity-based mechanism.

intensive), the key design elements that distinguish RES-E technologies are the ones aimed at properly assessing their expected firmness. Thus, maybe the crucial design element that characterises these auctions, especially when it comes to assess the future convergence of auctions for conventional and non-conventional generation, is the methodology to administratively determine the so-called firm capacity (or firm energy, or capacity credit, to mention other two of the many names that are used for this concept; in other words, what is the contribution of each generation unit to the system security of supply) as well as the penalties for not complying with this expectation.

Next, we face this discussion through the review of the main auction designs implemented to date in the South American region.

3. Long-term auctions review

3.1. Brazil

Brazil is the largest power system in the region. As mentioned in the introduction, its generation mix is dominated by a complex hydro system with plants spread over a vast area and with large reservoirs with multi-year storage capacity. Being such an important part of the demand covered by hydropower plants, hydrology has a large impact on the electricity market. When reservoirs are full, prices can be very low for a long period of time; on the other hand, during scarcity conditions, prices can reach high levels, tempting the Government to interfere in the spot prices, and introducing a large volatility that makes the risk of merchant investment in new capacity very high.

3.1.1. The 2004 reform

In order to solve this structural problem and to correct the initial market reform, which had not been able to guarantee the necessary expansion rates, a new regulatory framework was introduced in 2004, which has long-term electricity auctions as its backbone. This mechanism is based on two main pillars:

- All the demand (captive and free) must be 100% covered through electricity contracts and all contracts must be backed up by a physical coverage capability from the seller (firm capacity, firm energy, etc.). The compliance with this rule is verified monthly (ex post) by the Market Operator for the buyer (and the seller), based on the integral of the past 12-month of MWh consumed (availabilities) and contracted. Any positive difference between these two parameters is penalised at the maximum between the “cost of new energy” and the average of the spot prices during the same 12-month window.
- In order to pursue economic efficiency in the captive market, distribution companies can only procure contracts through auctions. Contracts are assigned through centralised electricity auctions organised by the Regulator. Free customers are not allowed to procure their electricity through these tenders and, as they must also be 100% covered by contracts, they should procure energy as they please.

All contracts are financial instruments and do not affect the dispatch, which is centrally managed by the system operator.

Separate auctions are organised for new and existing power plants. The so-called A1 auctions are designed as a sort of default service auctions i.e. to set the default tariff prices, (see Batlle [11]), and thus they are just targeted to existing power plants. The auction implementation details are similar to the A3 and A5 ones, which are described below, except for the fact that, since the objective is different (set tariffs in the short- to medium-term

versus bringing in new generation facilities), the contract due dates are much shorter (1-year lag period, 1–15 years contract duration, decided by the government).⁵

3.1.2. Long-term auctions for system adequacy and for reserve energy

When talking about long-term auctions, Brazil conducts two types of procurement processes: regular long-term auctions for system adequacy and auctions for reserve energy. The first type of auctions procures energy to supply the distribution companies' expected demand. These auctions are organised by the government, who carries out a joint procurement process for the loads forecasted and declared by distribution companies, and captive consumers pay the energy cost. On the other hand, reserve energy auctions are totally organised by the government, who defines the demand to be contracted and purchases supplementary capacity on the top of the one acquired in the regular auctions for system adequacy, i.e., energy to enhance the security of supply. The cost of these contracts is born by all consumers (regulated and free).

In both auction types, the final goal is to foster new investments by reducing the associated long-term risk. Contracts for electricity to be produced by new power plants should have large durations and in Brazil this is obtained by conducting two different auctions for system adequacy every year (with a 3- and a 5-year lag period, namely A3 and A5 auctions, respectively). In the case of reserve energy auctions, the lag period is usually of 3 years. Also contracts differ according to the technology (forwards for hydropower plants, energy call options for thermal plants and specific products for RES-E, as discussed next).

There is a long list of technical pre-requisites to register a candidate project to these auctions, including a prior environmental licence, a grid access statement, financial qualifications, technology-dependent documents (such as certified wind production or firm fuel supply agreement), etc.

Winning projects have to deposit several guarantees, including a bid bond of 1% of the project estimated investment cost and a completion bond of 5% of the project estimated investment cost. Several penalties are applicable in case of delays: during the period in which the plant is delayed, contract price is reduced, replacement firm energy contracts may be required depending on the auction type, and the regulator has the right to ask for contract termination if a delay higher than 1 year in any of the project milestones is observed.

One relevant feature is that, being both auction types based on a centralised procurement processes, each generator selected through the auction signs a bilateral contract with each distributor taking part to the auction, in proportion to their share of the total contracted energy.

From the structural point of view, the main advantage of the Brazilian auctions is the organisation and centralisation of the auction process, which allows the development of a smooth procurement process exploiting economies of scale.

To date, 11 A1 auctions, 15 between A3 and A5 auctions, and 6 reserve energy auctions have been carried out.

3.1.3. RES-E-specific auctions

In both auction types (regular or reserve), the Government can interfere in the candidate projects with policy decisions. The Government has used this option to organise exclusive auctions for specific large hydro projects, to avoid the participation of “polluting” sources, such as oil- and coal-fired generation, to

⁵ In the case of A1 auctions, adjustment auctions are available four times per year, with a lag period of 4 months and contract duration of 1–2 years. However, distribution companies can procure in these auctions only 1% of their demand.

Table 1
Results of recent auctions in Brazil. Data from [13].

	LFA ^a Aug 2010		LER ^b Aug 2010		Belo Monte ^c 2010		A-5 July 2010	
	MW	\$/MWh	MW	\$/MWh	MW	\$/MWh	MW	\$/MWh
Thermal	0	0	0	0	0	0	0	0
Hydro	0	0	0	0	11,233	47	730	55
Small hydro	101	88	31	78	0	0	79	92
Biomass	65	82	648	87	0	0	0	0
Wind	1520	80	528	73	0	0	0	0
Total	1686	81	1207	79	11,233	47	809	59
	A-5 Dec 2010		LER Aug 2011		A-3 Aug 2011		A-5 Dec 2011	
	MW	\$/MWh	MW	\$/MWh	MW	\$/MWh	MW	\$/MWh
Thermal	0	0	0	0	1029	58	0	0
Hydro	2120	39	0	0	450	57	135	50
Small hydro	0	0	0	0	0	0	0	0
Biomass	0	0	377	56	198	57	100	56
Wind	0	0	861	55	1068	55	977	57
Total	2120	39	1238	55	2745	57	1212	56
	A-5 Dec 2012		LER Aug 2013		A-5 Aug 2013		Summary 2010/2013	
	MW	\$/MWh	MW	\$/MWh	MW	\$/MWh	MW	\$/MWh
Thermal	0	0	0	0	0	0	1029	58
Hydro	292	48	0	0	445	55	15,405	54
Small hydro	0	0	0	0	154	64	364	78
Biomass	0	0	0	0	647	68	2035	70
Wind	282	45	1505	55	0	0	6740	62
Total	574	47	1505	55	1246	63	25,574	58

Small hydro: hydro plants with capacity < 50 MW and reservoir area < 3 km². FX rate: 2 BRL/USD.

^a A-3 auction restricted only to RES.

^b LER=Leilão de energia de reserva ("reserve energy auction").

^c Mega hydro plant auctioned in a separate process.

auctions (a standing practice since 2010), and to foster RES-E by means of exclusive auctions, which is the origin of the so-called RES-E auctions. In 2007, there was one regular auction where the candidate supply was restricted to bioelectricity and small hydro projects.

On the other hand, the reserve energy auction model has been strongly oriented towards non-conventional RES-E development since the very beginning: it was first implemented in 2008, in an exclusive auction for bioelectricity projects, and from 2009 it has been used to contract wind power projects. A specific product, catered to the peculiarities of wind power generation, was designed. This product has specific accounting mechanisms which allow wind farms to compensate in the long run for seasonal and inter-annual wind fluctuations, without compromising the project yearly cash flow, and this design was fundamental to allocate production risk, (see Porrua et al. [12]).

3.1.4. The price convergence

Table 1 shows the results of the most recent auctions held since 2010, illustrating how non-conventional RES-E are currently competing against conventional generation apparently in similar terms.

First of all it is noteworthy that Brazil has acquired from 2010 to 2013 some 25,500 MW at an average (all-in) energy price of 58 USD/MWh. From 2011, both wind and biomass generating units have taken part in the A3 and A5 and from these outcomes one could get the rushed impression that, from the price perspective, conventional and non-conventional generation technologies have already converged. However, as stated, this would be a rather hurried conclusion, as in the case of the A3 and A5 auctions, a number of auction design elements treat differently the diverse generation technologies and there is a difference in the product auctioned for hydro, thermal and wind resources. Next we discuss in more detail the main factors that need to be taken into account.

3.1.5. Firm energy certificates

As mentioned above, in Brazil, all contracts need to be covered by a calculated parameter that defines the contribution of the project to the security of supply. It is called firm energy certificate (FEC), also known as "physical guarantee" of each project, and it is calculated by the Ministry of Mines and Energy. The computation of the FEC of each project is a rather complex process, but can be summarised as follows:

- Before the auction, every hydro or thermal candidate project submits its technical data (variable costs, installed capacity, expected unavailability rates, historical record of inflows, etc.) to a planning company.
- This planning company computes the expected contribution to the energy security of supply of each thermal and hydro plant for a given supply reliability level. The same stochastic hydro-thermal scheduling tool used by the system operator to run the system is employed to simulate the joint operation of all assets in the system, for a set of synthetic inflow scenarios produced by a Monte Carlo simulation process, and to assess the FEC of each project.
- The FEC is a "paper" figure rated in MWh/year. For example, a 1 GW gas-fired plant with a 90% availability factor has a typical FEC of 1 GW (capacity) × 90% (availability) × 95% (FEC "factor") × 8.76 = 7489.8 GWh/year. A 1 GW hydro plant with a 98% availability factor would have a typical FEC of 1 GW (capacity) × 98% (availability) × 55% (FEC "factor") × 8.76 = 4721.6 GWh/year. The "FEC factor" is what translates the different installed capacities into comparable energy contributions to the system's security of supply (for a given reliability level).
- In case of hydro plants, the FEC is their expected production in dry years. In the case of thermal plants, the FEC depends on its variable operating costs: the lower the unit variable operating cost, the larger the FEC. Under this scheme, a thermal plant that is always available to produce, but whose costs are extremely

high would receive a close to zero firm energy because of its low energy contribution in dry periods (to prevent reservoir depletion).

- The FEC calculation of wind and biomass plants, however, is carried out based on the energy delivery commitment declaration signed by the agent in the power plant registration act. In case of wind plants, it corresponded to the production certified at the 50th percentile (“P50”) and in 2013 was revised to P90. In other words, for these RES technologies the FEC does not come from an integrated simulation of the plant within the hydro system, but it is a declaration by the agent.

3.1.5.1. FEC revision procedures. The FEC does not constitute a formal physical delivery obligation for hydro and thermal plants. This is due to the fact that these are dispatchable resources and their production pattern depends on the supply and demand balance and on the water resource availability. Nevertheless, this value is expected to naturally converge to the one observed in the FEC calculation procedure during critical supply periods, as the system operator uses the same scheduling models employed to calculate the FEC.

In all cases, during operation, the actual unavailability of the resources is measured. In the case of thermal plants, if the measured average unavailability is larger than the one declared for the FEC calculation, then the latter is reduced in the following year. The unavailability indexes are verified and updated in August every year based on the values gathered during the last 60 months (moving average). In case of hydro plants, the FEC can be reviewed every 5 years. In each revision, it cannot be changed by more than 5% and the limit for its total alteration throughout the project's concession is 10% of the value originally conceded. This rule is valid independently if the project has sold electricity in the regulated auctions or to free consumers.

In the case of wind installations, rules differ depending on which market the project has sold energy. Wind projects with sales in the regulated auctions have their FEC adjusted every four years to its average production observed in the four preceding years. Rules for wind projects with sales at the free market have not been defined yet.

This revision of the FEC value is in itself a way to penalise generation units for non compliance, and, as it has been presented, the revision is carried out differently for the different technologies. Besides, additional penalties are also implemented.

3.1.5.2. Penalties. In case a project has a reduction in its FEC, penalties apply. Hydro and thermal projects with sales in the regulated auctions or in the free market must buy replacement FECs in the market to make up for any FEC reduction that create a gap with the back up to their contracts. If replacement FECs are not procured, the penalty is as explained above: the maximum between the cost of new energy and the average of the spot price of the past 12 months.

In case of wind plants, however, different penalty rules apply for sales in the regulated market or through reserve auctions: in the latter case, the 4-year settlement has some fixed-price penalties for non-compliance, related to the project price.

As it can be observed, the different technologies clearly face different penalties and have different treatment in this sense.

3.2. Colombia

Although to a slightly lesser extent, the Colombian power sector is characterised by hydropower predominance and similar price volatility issues than Brazil. Initially, the regulatory

instrument implemented in order to attract new investment was a payment remunerating the available capacity of generation plants. However, especially in the case of hydro plants, the determination of the value of such capacity payment revealed to be a challenging task for the regulator and the scheme did not succeed in ensuring availability in scarcity conditions.

Therefore, in 2006 an innovative approach was implemented [7], whose conceptual basis was to “auction” the capacity payment, leaving the challenging task to the market. Finally the design of the scheme was commissioned to Cramton and Stoft [14] and it was introduced under the name of firm energy obligations (OEF, *Obligaciones de energía firme* in Spanish). The auctioned product is an annual payment, the so-called reliability charge, i.e. the remuneration required by the generator for being able to produce electricity during scarcity conditions for a fixed predetermined price (scarcity price or strike price). Scarcity conditions are identified as the periods of time when the spot market price exceeds a scarcity price set by the regulator and indexed to fuel prices.

These auctions are fully focused to guarantee system adequacy. Contrary to the Brazilian case, the regulator buys firm energy obligations on behalf of the whole system demand in a centralised auction.⁶ The lag period is set by the Regulator in each auction (usually around 4 years and larger ones, 10 years maximum, for the so-called GPPS auctions, aimed at large reservoir hydro plants) and the contract duration is up to 20 years. The demand is not considered as completely inelastic. When launching the auction, the regulator sets a demand curve, based on the so-called Cost of new Entrant.

Two OEF auction processes (2008 and 2011) have been carried out until now. In 2008 the resulting price was 14 USD/MWh. Besides 352 MW of new coal-fired plants and a 78 MW hydro plant, more than 2500 MW of new large hydro plants (expected to enter in operation from 2014 and so on) won the auction. In the case of the 2011 auctions, the resulting price was 15.7 USD/MWh and 410 MW of coal-fired plants and 167 MW of small hydro, in the subsequent GPPS auction, 2460 MW of hydro were assigned OEFs.

As it is the case of the Brazilian auctions, the factor that sets the difference between conventional generation and RES-E technologies is the procedure to calculate the firm energy, as well as the penalties established for non-compliance.

3.2.1. ENFICC, the Colombian firm energy certificates

In order to take part to the auction, generators must be backed by physical resources to be certified as capable of producing electricity during scarcity conditions. The Regulator has established methodologies for the calculation of these firm energy certificates (also called ENFICC) for the different technologies (see CREG, [15]).

- The ENFICC of hydraulic plants is calculated using a computational model (HIDENFICC, available in the web page of the regulator, CREG), which determines the maximum production that can be obtained monthly from a hydro plant during dry periods. The minimum ENFICC that a generator or investor can declare is denominated as *ENFICC Base* and corresponds to the minimum energy obtained from the maximisation model. The maximum ENFICC that can be declared to participate in the auction corresponds to the energy that a generator can produce

⁶ Distribution companies and free consumers are then supposed to cover their electricity demand independently, either through long-term contracts or in the spot market. Usually distribution companies cover the majority of their demand through contracts, signed individually.

Table 2
Results of recent auctions in Peru. Part of the data from [19].

	Law 28832		Proinversión 2011		RER Jan 2010		RER Aug 2011	
	MW	\$/MWh	MW	\$/MWh	MW	\$/MWh	MW	\$/MWh
Large hydro	202	36.7	544	48.25				
Thermal	154	40.7	854	90.63*				
Wind					142	81	90	69
Biomass					27	60.6	2	99.9
Small hydro					181	60.5	104	53.2
Solar					80	221.4	16	119.9

* US\$/kW-year.

with a probability of 95%, called ENFICC 95%. If the generator or investor chooses to declare an ENFICC higher than the ENFICC Base to participate in the auction, without exceeding the ENFICC 95%, the generator should back this difference with a financial warranty.

- The ENFICC of a thermal plant is calculated based on the generation capacity of the plant, the fuel availability, the number of hours per year and an index that incorporates the restrictions imposed on the plant, which limits its maximum energy generation. These restrictions are the historical forced outage rate and the constraints on the supply and transport of natural gas, in case generators use natural gas for their energy generation.

3.2.2. RES-E in the reliability charge mechanism

No explicit support mechanism for non-conventional RES-E is in force in Colombia to date, on the contrary, the Government until very recently had clearly stated that reducing carbon emissions is not a priority [3]. However, apparently the regulation is moving in a new direction. In 2010, through the Resolution no. 180919, the Ministry of Mines and Energy finally adopted an indicative action plan for the programme for the rational use of energy, defining specific targets of penetration of renewable energy in the power sector (3.5% in 2015 and 6.5% in 2020). Moreover, the draft Law 096 of 2012, which regulates the integration of non-conventional renewable energy to the National Energy System, establishes tax incentives, economic and/or financial resources for the generation and sale of non-conventional RES-E.⁷

In any case, at least from the regulatory perspective, the full integration of RES-E in the auction mechanism has already begun to take place. After some debate in literature⁸, since 2011, although not a single project was among the winners, wind installations could fully take part in the Reliability Charge auctions. Resolution 148/2011 [18] determines for the case of wind installations the procedure to calculate both the ENFICC Base and the ENFICC 95% (the maximum ENFICC that can be offered in the Reliability Charge auctions), dividing it between wind farms with and without 10-year wind speed studies. For those projects without 10-year wind speed studies, Resolution 148/2011 sets an ENFICC Base for wind farms that considers a contribution to the firm energy equal to 6% of their nominal power, which is well below the average load factors of this technology.

⁷ This proposal has been bitterly contested especially by the traditional generating companies, which argue that non-conventional RES-E should compete on equal terms with especially conventional hydro, which still has a very large potential in the country.

⁸ See for example Vergara et al. [16] and Botero et al. [17].

3.2.2.1. Penalties. The firm energy obligation is a daily obligation, this meaning that if the scarcity price (set originally in 2006 at around 100 USD/MWh but updated monthly according to the fluctuation of a portfolio of fuel indexes) is exceeded only in one hour, the generator has to guarantee firm energy during the entire day. The scarcity price automatically becomes a cap price in the short-term market for those generators selected through the auction. As regards capacity, generators have to cover a percentage of the demand profile equal to their percentage of firm energy in the auction. In case a generator is not able to fulfil its commitment during scarcity conditions, it must cover its obligation by acquiring electricity in the spot market, at the uncapped spot price, which will be higher than the scarcity price. Thus, wind generation, due to its non-dispatchability nature, is less competitive in providing such product.

3.3. Peru

After the 1992 liberalisation, the Peruvian electricity market was based on bilateral contracts between distributors and generators which were capped by the so-called busbar energy tariffs. These tariffs are calculated by the Regulator based on the expected average marginal price in each node. The determination of the busbar tariffs had always been a controversial issue and generators criticised its decoupling from the real marginal price. The situation became unsustainable in 2004, when the marginal price increased strongly without this being reflected in the energy tariff of regulated customers. As a consequence, generators decided not to renew existing contracts with distribution companies [10]. This finally resulted in 2006 in a new scheme reflected in the Law 28832 with the introduction of long-term electricity auctions, which were supposed to achieve a double aim, to define the energy tariff in a competitive way and at the same time serve as a tool to enhance the entry of new and efficient generation in the system. As it is the case in Chile, the capacity payment has remained in force and enters the energy contract through the calculation of an associated capacity.

The reform introduces the obligation for distribution companies to contract the expected demand of their captive consumers three years in advance (i.e. the lag period), signing contracts (with existing and new plants) that must have durations larger than five years for 75% of the demand. Even if the scheme is completely decentralised, a strong regulatory control on the auctions is applied. The auction format and indexation formulas must be approved by the Regulator, who also sets a price cap for each auction.

At the moment of setting the lag period and the contract duration for the auctions, the two abovementioned goals resulted in the choice of a compromise solution. However, the 5-year contract duration, initially targeted to attract gas-fired thermal plants with the objective of exploiting the new (at the time) gas resources in the country, was not considered sufficient later when the renewed objective turned to be to exploit the large hydropower potential of the country.

In 2011 the Government, through the Agency for the Promotion of the Private Investment (Proinversión) decided to launch a second type of auctions, enclosed in an extension of Legislative Decree 1041. These auctions targeted the construction of new hydropower plants (contract durations of 15 years) and dual-fuel (gas and diesel) turbines (20-year duration contracts). These tenders were project-specific and the lag period was also tailored to the project.

In September 2013 the Government announced the intention to submit to Congress a bill for the promotion of hydropower and a new call for tenders (again through Proinversión) for 1.1 MW of hydro plants.

Table 3

Comparison of the auction schemes used in Brazil, Colombia, and Peru.

	Brazil	Colombia	Peru
System-adequacy auctions			
Buying side	Captive demand	All-system demand	Captive demand
Auction process	Centralised	Centralised	Decentralised
Firm energy/capacity	FEC	ENFICC	Firm power + firm energy
Penalty	FEC reduction in case of underperformance + contracts not backed by FECs penalised at the maximum between the cost of new entrant and the average spot price	Implicit penalty (energy not delivered must be replaced and procured at the spot price)	Implicit penalty (power and energy not delivered must be replaced and procured at the short-term price)
Potential RES-E participation	Yes	Yes	Yes
Actual RES-E participation	Yes (wind power)	No	No
Conventional/RES-E discrimination	Different provisions (FEC based on a declaration of the project promoter; different settlements in case of underperformance)	Same provisions	Same provisions
Renewable energy auctions			
Remuneration	Long-term contract at fixed price from the auction	No specific renewable energy auction in place	Premium on the top of the short-term market price for achieving 12% rate of return
Firm energy	Calculated and declared by the project promoter		Calculated and declared by the project promoter
Specific penalty	No (same penalties as in the case of system-adequacy auctions)		Yes (complex penalisation scheme with explicit penalty in case of underperformance)

3.3.1. The RER auctions

In 2008, Peru decided to implement a support scheme for RES-E development in the country. Decree 1002/2008 introduced a mechanism of incentives for those projects exploiting non-conventional RES-E the so-called RER technologies, wind, biomass, small hydro (less than 20 MW) and solar. The mechanism considers a premium on the top of the market price in order to guarantee a 12% rate of return, which must be assigned through competitive bidding and it is settled once a year.

Despite the complex technicalities of the scheme, also the Peruvian mechanism can be considered as based on a renewable auction that fixes the remuneration for generators. The selected bidders sign 20-year contracts directly with the Ministry of Energy and Mines and the premia are collected from end-customers through a surcharge included in the access tariff.

This remuneration scheme is implemented through an ex-ante calculation by OSINERGMIN, which is based on spot market price estimations for the following year, and monthly payments to the generators. Unbalances between the expected and the real spot market price or between the contracted and the actual electricity injections of the generators are settled once a year and included in the following year remuneration. However if the energy produced exceeds the contracted one, the difference is settled at the market price and not at the contracted remuneration.

Table 2 shows the results of recent auctions held, both for conventional and RER technologies.

3.3.2. Penalties

Contracts signed under the framework of Law no. 28832 auctions consider both power and energy.

- The Firm Power is the maximum continuous power that can be produced by a generator, complying with a security criterion, specified in the COES Proceeding no. 26.
- The Firm Energy is the maximum electricity production in scarcity conditions. For thermal plants it is based on the

expected unavailability, whereas for hydro plants a conservative calculation is applied, following COES Proceeding no. 13.

The difference between the energy actually produced by a generator and the contracted one is settled at the short-term market price. For the power, the reference price is calculated by OSINERGMIN taking into account the marginal cost of covering an extra kW of demand through the installation of a peaking thermal unit (in 2012 this parameter was equal to 83.06 USD/kW-year [20]). The difference between the power actually supplied to the network and the contracted one is settled at this power price. Therefore the only penalty considered by these contracts is an implicit one. This is also the case of the plants which entered the system through the Proinversion auctions.

In the case of RES-E plants entering Decree 1002 auctions, the mechanism includes an explicit penalisation scheme which is applied whenever the energy injected in a year is less than the contracted one. The penalisation factor used is equal to the percentage of the missing energy over the contracted one and it is multiplied by the total remuneration received for that year. This explicit penalisation is collected in the following year settlement. However, being the settlement of this penalty carried out on a yearly basis, what is penalised is not the non-dispatchability and the intermittency of the RES-E technologies (which occurs in the short term), but rather the underperformance due to an overestimation of the load factor of the plant by the project promoters (that is related to the long term and can be checked on a yearly basis).

When comparing RES-E and conventional technologies, another difference that must be taken into account lies in the fiscal incentive for renewable generators. Decree 1058/2008 introduced a scheme of accelerated depreciation equal to 20% per year (this means a 5-year tax postponement) for all the investments on machines, equipment and constructions of RES-E projects.

3.4. Comparison

The discussion provided above regarding the interaction between system-adequacy and renewable energy auctions is

summarised in Table 3 for the three countries (Brazil, Colombia, and Peru) where this phenomenon is more clearly observable. Brazil is the country where this interaction is more evident, with RES-E technologies entering the system not only through renewable-specific auctions, but also through standard system-adequacy auctions. However, as highlighted in the table, this entrance is favoured by the different contract provisions, in terms of firm energy calculation and penalties for underperformance, which discriminate in favour of RES-E technologies. On the other hand, in Colombia, where no renewable-specific auction is in place, the only entry point for RES-E technology is the system-adequacy auction. However, due to the daily settlement of the contract auctioned in this tender, the competitive position of non-dispatchable generation technologies is weakened, and no penetration of RES-E in these auctions has been observed. Finally, in Peru no RES-E participation to system-adequacy auctions has taken place and renewables are entering the system exclusively through RES-E specific auctions, characterised by a comprehensive penalisation scheme.

3.5. Other approaches

Besides Brazil, Colombia, and Peru, where system-adequacy and RES-E auctions have already started interacting and for which a detailed analysis of the potential convergence of these mechanisms is possible, there are other South American countries that have introduced long-term electricity auctions. For these systems it is not possible to provide an inclusive comparison of the auctions as for the above-analysed countries, either because only one regulatory objective (system adequacy or RES-E support) is being pursued through long-term auctions or due to the current lack of overlapping of these mechanisms. These auctioning schemes are briefly presented in this section for the sake of completeness.

3.5.1. Chile

System-adequacy auctions were introduced in Chile in 2004, through the so-called Short Laws I and II, as a response to the limitations shown by the previous regulatory system during the dry years at the end of the 1990s. The target of the reform is to hedge only the captive demand (regulated customers), so distribution companies are required to cover 100% of the consumption of their customers through long-term contracts to be procured by auctions. The difference from the Brazilian case (more in line with the Peruvian scheme) is that the Chilean distributors are supposed to organise the auctions on their own, choosing their preferred design and auction mechanism. The government only sets a price cap and ranges for the lag period and the contract duration. The entire process is therefore decentralised, but joint auctions coordinated by a group of distributors are allowed. The most common auction design used is combinatorial auction, where several different products are procured at the same time.

Theoretically the contracts are not supposed to be covered by any availability certificate and it is up to distribution companies to evaluate the bidders' credibility when calling the auction. Nonetheless, generators have to specify to the regulator, on a yearly basis, which plants will be used to cover the contracted demand. This can be done through a combination of existing and projected plants. Therefore in Chile existing and new plants compete in the same auction. It is important to note how in the Chilean case, as in the Peruvian one, capacity payments have not been cancelled with the implementation of long-term auctioning. To date, several auctions have been launched by distribution companies, but, due to the decentralised approach, these figures are not comparable with those from other schemes.

3.5.2. RES-E support

Chile does not rely on long-term auctions to support the penetration of non-conventional renewable energy in the power sector. Some form of incentive was already contained in the Short Laws I and II, which firstly identified non-conventional renewable energy sources (ERNC, from the Spanish, *Energía Renovable No Convencional*) and introduced a series of advantages for RES-E technologies, in terms of connexion facilitations and access-tariff exemption.

Nevertheless, the main RES-E support scheme was introduced in 2008 through the Law no. 20.257 and is based on quotas. The system is based on the obligation for the demand (according to the Law, all those electric companies that withdraw energy from the electricity system for its retailing, i.e. distribution companies) to cover a certain percentage of its load through RES-E technologies. This percentage is not fixed, but follows an increasing profile defined by the Regulator (from 5% in 2010 to 10% in 2024).⁹

3.5.3. Argentina

Argentina reformed its power sector in 1992, but the development of the liberalisation was blocked and jeopardised by the 2001 economic crisis. Consequently, Argentina did not followed other South American countries in the second wave of regulatory reforms, which introduced long-term electricity auctions for securing coverage of future demand.

The only initiative resembling long-term electricity auctions is the so-called Energy Plus Programme, implemented in 2006. The underlying principle of this "silent reform" of the Argentinean power sector is that captive demand (residential users and small commercial and industrial users, served by distribution companies) have the priority on the electricity traded in the short-term market. Practically, the resolution obliges all those consumers with contracted capacities above 300 kW to cover their electricity demand exceeding their base demand, i.e. their electric power demand in 2005, in a new term market, the Energy Plus Market, in which only new generation plants can sell electricity. Those Energy Plus consumers who were not able to sign any contract to back their demand increase can request the Secretary of Energy to organise an auction to cover the sum of their power requirements. However, to date, there is no information regarding any auction carried out under this scheme.

3.5.4. RES-E support

In order to achieve the 8% RES-E target set by the National System for the promotion of electricity from RES within 2016, the Secretary of Energy, under the framework of the GENREN Programme (Decree 562/09), required the State-owned utility ENARSA to contract 1015 MW of new capacity from RES-E technologies, through a proper call for bids, in which bidders propose a fixed remuneration for each MWh produced by the plant to be installed. ENARSA received bids for a volume of 1436.5 MW, exceeding 40% the initial target. After the technical and economic evaluation of the proposals, only 895 MW were accepted, with prices ranging from 127 USD/MWh for wind turbines to 572 USD/MWh for photovoltaic plants. The estimation of the energy deliverable by the RES-E generation plant is left to project developers. The only penalisation considered by the GENREN Programme is a daily 1000 USD/MW in case of delays in construction.

⁹ Apparently, the framework described in this section has been modified by Law 20698 of October 2013, which sets a more ambitious target for RES-E penetration and, in order to achieve it, introduces renewable energy auctions. Due to the lack of relevant rules and regulations at the moment of this writing, it was not possible to include this mechanism in this article.

3.5.5. Uruguay

The vast majority of the generation segment of the Uruguayan power sector is controlled by the State, therefore the system adequacy is obtained through a centralised management of the Regulator. However, the State has recently started to implement power purchase agreements with private RES-E generators. Under the framework of its Wind Energy Programme, Uruguay has contracted in the last three years around 880 MW of wind generation through long-term auctions. The last of the three auctions carried out until now resulted in an average price equal to 63 USD/MWh.

4. Conclusions

Long-term electricity auctions are nowadays the main driver for capacity expansion of the electricity systems in South America, where they have acquired during the last decade a central role in the regulation of several countries. Initially, the auctioning schemes represented a new capacity mechanism, which fosters the investment in new generation plants by competitively assigning long-term contracts that fix part of the generators remuneration, thus hedging their risks. Nonetheless, following this regulatory trend, recently these mechanisms have started being used also for the promotion of non-conventional renewable energy technologies.

At the beginning, these two contexts were considered as separated. Conventional technologies (large hydro, fossil-fuels thermal plants) competed in the system-adequacy auctions and non-conventional renewable energy technologies in the RES-E-specific auctions. The former were supposed to involve large quantities of energy (or firm energy) at market price, while the latter should cover lower quantities at relatively higher prices. However, as detailed in the paper, the most recent RES-E-specific auctions carried out in Brazil and Peru contracted renewable energy supply at very competitive prices, difficult to be imagined just a few years ago.

These until-now separated schemes, system-adequacy auctions and RES-E-specific auctions, seem then to be close to convergence, and this idea can be reinforced by the participation of wind energy projects in recent Brazilian conventional A3 and A5 auctions and by the issue of CREG Resolution 148/2011, which allows wind farms to take part in the Colombian reliability charge mechanism.

Nevertheless, as we have thoroughly discussed and evidenced, in all those countries and regulations where these mechanisms seem to be merging together, it is possible to observe how conventional and renewable technologies are still far from competing under parity of conditions. The main differential factor lies on the way the contribution to the security of supply of these technologies is assessed and settled (namely the firm energy/capacity calculation methodology and the penalties for noncompliance in the provision of the energy supply) and the implication this issue has on the design of the products for each technology and impede, at the moment, to level the playing field to have full competition between them.

Acknowledgements

We would like to thank Manuel Uribe from the Peruvian regulator OSINERGMIN and José Salazar from Empresas Públicas de Medellín (Colombia) for their support and fruitful comments.

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